MycoKeys

MycoKeys 130: 185–208 (2026)
DOI: 10.3897/mycokeys.130.183859

Research Article

Taxonomy and phylogeny reveal new species of *Volvariella* (Volvariellaceae, Agaricales) and *Volvopluteus* (Pluteaceae, Agaricales) from eastern India

Entaj Tarafder[1], Enjamul Hoque[2], Ang Rinzing Sherpa[2], Samantha C. Karunarathna[1], Meimei Wang[1], Nalin N. Wijayawardene[1,3], Qiang Li[1], Fuqiang Yu[3], Dong-Qin Dai[1], Wannapawn Watsuntorn[4]

1 *Center for Yunnan Plateau Biological Resources Protection and Utilization & Yunnan International Joint Laboratory of Fungal Sustainable Utilization in South and Southeast Asia, College of Biology and Food Engineering, Qujing Normal University, Qujing 655099, China*
2 *Department of Botany, West Bengal State University, N.24 Parganas, Barasat 700126, West Bengal, India*
3 *Germplasm Bank of Wild Species & Yunnan International Joint Laboratory of Fungal Sustainable Utilization in South and Southeast Asia, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming 650201, China*
4 *High-Value Food from Mushrooms and Bioactive Plants in the Green Economy Value Chain Research Group, The Institute of Biotechnology and Genetic Engineering, Chulalongkorn University, 254 Phayathai Road, Pathumwan, Bangkok, 10330, Thailand*

Corresponding authors: Dong-Qin Dai (cicidaidongqin@gmail.com); Wannapawn Watsuntorn (wannapawn.w@chula.ac.th)

Abstract

Volvariella areolavolvata **sp. nov.** and *Volvopluteus fibrillobrunneus* **sp. nov.** are introduced and illustrated from West Bengal, eastern India, based on detailed morphological observations and molecular phylogenetic analyses. Morphologically, *V. areolavolvata* is distinguished by its large-sized basidiomata with a pileus covered by conspicuous silky fibrils, becoming slightly yellowish at the center with age; the presence of a volva with a distinctive, externally areolate cracked surface; oval to ellipsoid basidiospores with a mean value of 7.75 × 4.91 µm; mostly lageniform cheilocystidia, 63–131 × 21–37 µm; and broadly clavate pleurocystidia with a rounded apex, 44–56 × 13–17 µm. *Volvopluteus fibrillobrunneus* is characterized by a pileus with light brown to greyish-brown fibrils; ellipsoid to elongate basidiospores (mean 9.85 × 6.30 µm); mostly clavate cheilocystidia measuring 34–72 × 15–29 µm; and rostrate pleurocystidia with prominent apical appendages, 53–75 × 14–21 µm. Phylogenetic analyses based on combined nrITS and nrLSU sequence data support the recognition of both taxa as distinct species within *Volvariella* and *Volvopluteus*, respectively, forming well-supported clades clearly separated from their closest species. Detailed morphological descriptions, field photographs of the collected basidiomata, comparisons with morphologically similar taxa, and phylogenetic analyses based on the combined nrITS and nrLSU sequence datasets are provided.

Key words: Basidiomycota, morphological characteristics, phylogenetic analysis, two new species

OPEN ACCESS

Academic editor: Thorsten Lumbsch
Received: 30 December 2025
Accepted: 19 February 2026
Published: 24 March 2026

Citation: Tarafder E, Hoque E, Sherpa AR, Karunarathna SC, Wang M, Wijayawardene NN, Li Q, Yu F, Dai D-Q, Watsuntorn W (2026) Taxonomy and phylogeny reveal new species of *Volvariella* (Volvariellaceae, Agaricales) and *Volvopluteus* (Pluteaceae, Agaricales) from eastern India. MycoKeys 130: 185–208. https://doi.org/10.3897/mycokeys.130.183859

Copyright: © Entaj Tarafder et al.
This is an open access article distributed under terms of the Creative Commons Attribution License (Attribution 4.0 International – CC BY 4.0).

Introduction

The genus *Volvariella* Speg. was established by Spegazzini (1898) with *Volvariella argentina* Speg. as the type species. Members of the genus are widely distributed across temperate, subtropical, and tropical regions (Mehrotra

and Aneja 1990). They are mostly found as saprobes on soil, in grasslands, on forest litter, and occasionally on decaying wood. Species of *Volvariella* are characterized by their pluteoid basidiomata, free lamellae, the presence of a membranous volva at the stipe base, a pinkish spore print, smooth and inamyloid basidiospores, and an inverse hymenophoral trama (Singer 1986; Orton 1986; Boekhout 1990; Kaygusuz et al. 2020; Kalichman et al. 2020; Kumla et al. 2022). However, in some studies, *Volvariella* was placed within the family Pluteaceae based on morphological similarities with the genus *Pluteus* (Justo et al. 2011a). Later, molecular phylogenetic studies showed that *Volvariella* s.l. is polyphyletic (Matheny et al. 2006).

Subsequent multi-gene phylogenetic analyses demonstrated that the *Volvariella*-like species with basidiospore lengths shorter than 11 µm and possessing a gelatinous ixocutis-type pileipellis form a distinct clade from *Volvariella s.str.* and are more closely related to the genus *Pluteus* (Justo et al. 2011a). This led to the segregation of the genus *Volvopluteus* Vizzini, Contu & Justo to accommodate these taxa, which are distinct from *Volvariella s.str.* and *Pluteus s.str.* (Justo et al. 2011a, 2011b). More recently, based on six-loci phylogenetic analyses, Volvariellaceae Vizzini, Consiglio & P. Alvarado was introduced to accommodate *Volvariella s.str.* within the order Agaricales (Vizzini et al. 2024). More than 147 species of *Volvariella* have been described around the world (Chattopadhyay et al. 2022; Vizzini et al. 2024; Hussain et al. 2025). To date, 22 species of *Volvariella* have been reported in India (Table 1), of which only eight have been reported from West Bengal, eastern India (Dutta et al. 2011, 2013; Chattopadhyay et al. 2022).

The genus *Volvopluteus* is typified by *Volvopluteus gloiocephalus* (DC.) Vizzini, Contu & Justo as the type species. Species of *Volvopluteus* are characterized by medium- to large-sized basidiomata, free lamellae, a pinkish spore print, the presence of a volva at the stipe base, inamyloid, subglobose to broadly ellipsoid basidiospores, and a gelatinous ixocutis-type pileipellis (Justo et al. 2011a; Kaygusuz et al. 2021). To date, only 12 species have been listed in Species Fungorum (www.speciesfungorum.org; accessed on 12 December 2025), viz. *Vp. asiaticus* Justo & Minnis, 2011, *Vp. canalipes* (Murrill) Montoya, Bandala & Esqueda, 2021, *Vp. delicisus* Chuan H. Li & T.H. Li, 2025, *Vp. diversisporus* M. Kaur & Yadw. Singh, 2014, *Vp. earlei* (Murrill) Vizzini, Contu & Justo, 2011, *Vp. gloiocephalus* (DC.) Vizzini, Contu & Justo, 2011, *Vp. longipes* Xue T. Zhu & L. J. Liu, 2025, *Vp. michiganensis* (A.H. Sm.) Justo & Minnis, 2011, *Vp. platensis* Xue T. Zhu & L. J. Liu, 2025, *Vp. shafferii* M. Kaur & Yadw. Singh, 2014, and *Vp. yunnanensis* D.G. Zheng & Karun., 2025. Among these, only two species have been reported from India, viz., *Vp. diversisporus* and *Vp. shafferii* (Table 1). However, both records are currently considered invalid in MycoBank (https://www.mycobank.org; Zheng et al. 2025). Importantly, no species of *Volvopluteus* has been reported from West Bengal in eastern India.

During repeated field surveys conducted from 2024 to 2025 in Barasat, West Bengal, India, several specimens belonging to the families Volvariellaceae and Pluteaceae were collected. Among the new collections, two new species belonging to *Volvariella* and *Volvopluteus* are introduced based on morphological characteristics and combined (nrITS and nrLSU) phylogenetic analyses. Detailed descriptions, illustrations, and phylogenetic analysis results of the two new species are presented.

Table 1. List of *Volvariella* and *Volvopluteus* species reported from India, showing their state-wise distribution and relevant references.

Species	State	Reference
Volvariella apalotricha	Kerala	Pradeep et al. (1998)
V. bombycina	Kerala, Rajasthan	Pradeep et al. (1998); Chouhan and Panwar (2021)
V. bilobata	West Bengal	Chattopadhyay et al. (2022)
V. castanea	West Bengal, Uttar Pradesh,	Massee (1912); Pathak et al. (1978)
V. cubensis	Kerala	Mohanan (2011)
V. delicatula	West Bengal, Uttar Pradesh	Massee (1912); Pathak et al. (1978)
V. diplasia	West Bengal, Uttar Pradesh	Bose (1920a); Rath (1962); Pathak et al. (1978)
V. earlei	Rajasthan	Chouhan and Panwar (2021)
V. glandiformis	Kerala	Pradeep et al. (1998); Mohanan (2011)
V. hypopithys	Kerala, Rajasthan	Pradeep et al. (1998); Chouhan and Panwar (2021)
V. indica	Punjab	Kaur et al. (2013)
V. media	Tripura	Roy Das et al. (2017)
V. murinella	Assam	Gogoi and Prakash (2015)
V. nigrodisca	Kerala	Pradeep et al. (1998); Mohanan (2011)
V. pseudovolvacea	Kerala	Pradeep et al. (1998); Mohanan (2011)
V. pusilla	Kerala, West Bengal, Rajasthan	Pradeep et al. (1998); Dutta et al. (2011); Chouhan and Panwar (2021)
V. sathei	Maharashtra	Senthilarasu et al. (2012)
V. taylorii	Kerala, Mizoram	Pradeep et al. (1998); Mohanan (2011); Lalrinawmi (2019)
V. terastia	Kerala, West Bengal, Uttar Pradesh	Bose (1920b); (1921); Rath (1962); Pathak et al. (1978); Manimohan et al. (1988)
V. thwaitesii	West Bengal, Uttar Pradesh	Berkeley (1850); Pathak et al. (1978)
V. volvacea	Kerala, West Bengal, Assam, Tripura	Lakshmanan et al. (1979); Pradeep et al. (1998); Florence (2004); Manimohan et al. (2007); Pradeep and Vrinda (2007); Dutta et al. (2011); Mohanan (2011); Gogoi and Prakash (2015); Swargiari and Buragohain (2018); Basumatary and Gogoi (2016); Debnath et al. (2020)
V. woodrowiana	Maharashtra, Uttar Pradesh	Massee (1899); Pathak et al. (1978)
Volvopluteus diversisporus (Nom. inval., Art. F.5.1)	Punjab	Kaur and Singh (2014)
Vp. shafferii (Nom. inval., Art. F.5.1)	Punjab	Kaur and Singh (2014)

Materials and methods

Sample collection and morphological observation

Fresh basidiomata of *Volvariella* and *Volvopluteus* were photographed in situ at Talikhola and Kazibari, Barasat, West Bengal, India. Collection details were recorded (Shaffer 1957; Boekhout 1990; Rathnayaka et al. 2024), and the specimens were taken to the laboratory at West Bengal State University in plastic collection boxes. Morphological descriptions of the specimens were made following Largent et al. (1977). For color terminology, Kornerup and Wanscher's (1978) color code was strictly followed. Collected specimens were dried at 45–50 °C with an electric food dryer (Hu et al. 2022).

For microscopic characterization, thin sections from multiple basidiomata were revived in 5% KOH and stained with a 1% Congo red solution (Tarafder et al. 2023; Lu et al. 2024). The notation [30, 2, 1] indicates that measurements were conducted on a total of 30 basidiospores obtained from a multiple-sample collection at a specific time point. Additionally, the abbreviations X_m, Q, and Q_m represent the following: X_{mr}, the range of basidiospore arithmetic means of

the spore length by spore width (± standard deviation), and X_{mm}, the mean of basidiospore means (± SD); Q, the quotient of basidiospore length/width, indicated as a range of variation in n spores measured; Q_{mr}, the range of Q_m values, and Q_{mm}, the mean of Q_m values; n, the number of basidiospores measured; and s, the number of specimens involved, with the standard deviation specified. Dried voucher specimens were deposited in the Central National Herbarium (CAL).

DNA extraction, PCR amplification, and sequencing

Genomic DNA was extracted from the herbarium specimens using the E.Z.N.A.® Fungal DNA Mini Kit (Omega Bio-Tek, Inc., Norcross, USA), with slight modifications to the manufacturer's protocol and to the protocol described in earlier studies (Tarafder et al. 2022, 2023). After DNA extraction, the primer pairs ITS1 and ITS4 (White et al. 1990; Gardes and Bruns 1993) were used to amplify the internal transcribed spacer (nrITS) gene regions of ribosomal DNA, and LR0R and LR3 (Vilgalys and Hester 1990) were used to amplify nrLSU. The DNA fragments were amplified on an Applied Biosystems 2720 automated thermal cycler, following the methods described by Dutta et al. (2017) and Tarafder et al. (2022). PCR amplification was carried out in a 25 µL reaction volume, which consisted of 12.5 µL of 2× Bench Top™ Taq Master Mix, 9.5 µL of ddH2O, 1 µL of each primer (10 µM), and 1 µL of genomic DNA. The PCR thermal cycling programs for nrITS and nrLSU amplification were as follows: an initial denaturation at 94 °C for 4 minutes, followed by 35 cycles of denaturation at 94 °C for 30 seconds, annealing at 56 °C for 45 seconds, elongation at 72 °C for 1 minute, then a final extension at 72 °C for 7 minutes, and storage at 4 °C. Following amplification, the PCR products were purified with the QIAquick® Gel Extraction Kit (QIAGEN, Germany) and sequenced with the primers listed in Table 2 using the commercial sequencing provider GeneSpec Pvt. Ltd. (Karnataka, India). All newly generated sequences in this study were deposited in GenBank (https://www.ncbi.nlm.nih.gov/genbank/) and listed in Table 3.

Table 2. Information on loci and primers used in this study.

Loci	PCR primers (forward/reverse)	Primer sequences	References
ITS	ITS1	TCCGTAGGTGAACCTGCGG	White et al. (1990)
	ITS4	TCCTCCGCTTATTGATATGC	
LSU	LR0R	ACCCGCTGAACTTAAGC	Vilgalys and Hester (1990)
	LR3	CCGTGTTTCAAGACGGG	

Dataset representation

The amplified sequences were checked for quality, assembled using the BioEdit Sequence Alignment Editor version 7.2.5 (Hall 1999), and used to perform BLASTn searches against the NCBI GenBank database (https://blast.ncbi.nlm.nih.gov/Blast.cgi). Subsequently, closely related sequences of the taxa with zero E-values were retrieved from the database to generate the dataset. Additionally, the sequences used in earlier studies on *Volvariella* and *Volvopluteus* (Justo et al. 2011a; Malysheva et al. 2019; Chattopadhyay et al. 2022; Zheng et al. 2025) were also obtained from the database to prepare the final dataset (Table 3). The sequence of *Cantharocybe gruberi* has been used as an outgroup taxon as per the study by Malysheva et al. (2019).

Sequence alignment and phylogenetic analyses

The combined nrITS and nrLSU datasets were aligned in the CIPRES XSEDE resource using the online program MAFFT v7.427 (Katoh and Standley 2016; Katoh et al. 2019). The aligned sequences were then imported into Aliview v1.17.1 (Larsson 2014) for manual improvement and trimming of both ends.

In the CIPRES web portal (http://www.phylo.org/portal2/) (Miller et al. 2012), jModelTest 2.1.10 v20160303 (Darriba et al. 2012) was used to identify a statistically suitable model for the given dataset to perform Maximum likelihood (ML) analysis. The GTR+I+G model was chosen for the dataset based on the lowest BIC value of 14452.082637.

Maximum likelihood analysis was performed with RAxML-HPC2 v8.2.12 (Stamatakis 2014) on the CIPRES XSEDE resource using the selected model from jModelTest 2.1.10 v20160303, with 1,000 bootstrap replicates. Bayesian analyses (BA) were conducted with MrBayes v3.2.2 (Ronquist et al. 2012) using MCMC methods (Geyer 1991) under a GTR+I+G model. Markov chains were run for 1×10^6 generations, saving a tree every 1000th generation, with all remaining parameters set to default. The average standard deviation of split frequencies reached 0.013 at the end of the run. Convergence was further assessed by examining effective sample size (ESS) values and potential scale reduction factor (PSRF) values. ESS values for all parameters exceeded 200, including the log-likelihood (lnL) with an ESS of 215, indicating adequate sampling of the posterior distribution. PSRF values for all parameters were close to 1.00, confirming convergence among independent runs. The initial 25% of recovered trees were excluded as burn-in, and the remaining trees were then used to estimate the posterior probabilities of the group. ML bootstrap values (MLBS) ≥ 50% and Bayesian posterior probability (PP) values ≥ 0.90 are reported in the resulting tree (Fig. 1). The phylogenetic trees were visualized and edited using FigTree v1.4.0 software (Rambaut and Drummond 2012).

Results

Phylogenetic analyses

The phylogenetic analyses were conducted using combined nrITS and nrLSU rDNA datasets. A total of 87 sequences were aligned, and the ends of each were subsequently trimmed. This resulted in a dataset consisting of 1,547 nucleotides; after trimming the ends of the individual alignments, the aligned datasets were 702 bp for nrITS and 845 bp for nrLSU, including gaps. The combined alignment comprised 649 parsimony-informative characters, 142 singleton sites, and 961 constant characters. The estimated base frequencies were as follows: A = 0.251, C = 0.215, G = 0.316, T = 0.218; substitution rates AC = 2.22735, AG = 5.33961, AT = 2.22735, CG = 1.00000, CT = 16.55070, GT = 1.00000. The phylogenetic tree derived from ML and MrBayes analyses exhibited nearly identical topology. Therefore, the tree obtained from ML analysis (−*lnL* = 14452.082637) has been displayed in the present manuscript (Fig. 1), and the support values recovered from ML (MLBS ≥ 50%) and BA (PP ≥ 0.90) are presented.

In the phylogenetic tree (Fig. 1), taxa belonging to the genera *Volvariella* and *Volvopluteus* are separated from each other, and each genus appears monophyletic for the included taxa.

Table 3. Names, voucher numbers, country of origin, and corresponding GenBank accession numbers of the taxa used in the phylogenetic analysis.

Taxon name	Specimen voucher	Country of origin	GenBank accession no.		References
			nrITS	nrLSU	
Volvariella areolavolvata	**CAL 2383[T]**	**India**	**PX776811**	**PX764990**	**This study**
V. areolavolvata	**CAL 2384**	**India**	**PX776812**	**PX764991**	**This study**
V. bilobata	CUH AM778	India	ON922568	-	Chattopadhyay et al. (2022)
V. bilobata	GUBH 19922	India	ON922564	-	Chattopadhyay et al. (2022)
V. bombycina	AJ244	Spain	HM562212	HM562256	Justo et al. (2011a)
V. bombycina	SDBR-CMUNK0726	Thailand	OM417508	OM373644	Kumla et al. (2022)
V. caesiotincta	MA54717	Spain	HM562211	HM562255	Justo et al. (2011a)
V. cf. *sathei*	Hama390	Niger	KF926666	-	Daniëls et al. (2015)
V. cubensis	ARF-4948	USA	OP580290	-	GenBank
V. diplasia	CBS 355.64	India	MH858454	MH870086	Vu et al. (2019)
V. dunensis	JAC10587	New Zealand	MN738630	-	Unpublished
V. dunensis	SCM3513	Spain	JF415140	-	Vizzini et al. (2011)
V. hypopithys	TO AV137	Italy	HM246492	HM246488	Unpublished
V. krizii	PR1516257	Czech Republic	-	MK770133	Kaygusuz et al. (2020)
V. lanata	LE F-347402	Russia	OR872182	-	Malysheva and Malysheva (2024)
V. lanata	LE F-347403	Russia	OR872183	-	Malysheva and Malysheva (2024)
V. lepiotospora	AJ155	USA	HM562214	HM562259	Justo et al. (2011a)
Vp. earlei	TO HG2001	Italy	HM246498	HM246477	Justo et al. (2011b)
V. morozovae	LE 313229	Vietnam	MF377507	MF377508	Crous et al. (2017)
V. morozovae	LE 313322	Vietnam	MK882994	-	Crous et al. (2017)
V. murinella	GLM-F43392	Germany	MK412361	-	Unpublished
V. murinella	GLM-F42624	Germany	MK412400	-	Unpublished
V. murinella	G0742	Hungary	-	MK278657	Varga et al. (2019)
V. neovolvacea	SDBR-CMUNK0758	Thailand	OM417503	OM373653	Kumla et al. (2022)
V. neovolvacea	SDBR-CMUNK0760	Thailand	OM417505	-	Kumla et al. (2022)
V. nivea	GDGM 25489	China	FJ749127	-	Li et al. (2009)
V. nullicystidiata	SP393639	Brazil	EU920671	EU920670	Menolli Jr and Capelari (2008)
V. orientalis	LE 313241	Vietnam	MK882999	-	Malysheva et al. (2019)
V. orientalis	LE 313654	Vietnam	OL415619	-	Malysheva et al. (2019)
V. pulla	LE 313325	Vietnam	MK882998	MK883003	Malysheva et al. (2019)
V. pusilla	TO AV139	Italy	HM246494	HM246479	Unpublished
V. reidii	FI-1.2	Finland	MK770140	-	Kaygusuz et al. (2020)
V. reidii	FI-1.1	Finland	MK770139	-	Kaygusuz et al. (2020)
V. rostricystidiata	MFLU19-1528	Thailand	MT074694	MT078695	Niego et al. (2021)
V. rostricystidiata	MFLU19-1531	Thailand	MT074695	MT078696	Niego et al. (2021)
V. sathei	AMH 9436	India	JN792550	-	Senthilarasu et al. (2012)
V. strangulata	TO AV141	Italy	HM246493	HM246484	Unpublished
V. surrecta	AJ55	Spain	HM562213	HM562254	Justo et al. (2011a)
V. surrecta	GLM-F61563	Germany	MK412358	-	Unpublished
V. surrecta	G0848	Hungary	-	MK278659	Unpublished
V. taylorii	AJ54	Portugal	HM562210	HM562260	Justo et al. (2011a)
V. terrea	LUG11010	France	JF415141	-	Vizzini et al. (2011)
V. terrea	K(M):195631	United Kingdom	MZ159529	-	Unpublished
V. thailandensis	SDBR-CMUNK0957	Thailand	OM417504	-	Kumla et al. (2022)

Taxon name	Specimen voucher	Country of origin	GenBank accession no.		References
			nrITS	nrLSU	
V. volvacea	JAC12235	New Zealand	MN738642	MN738572	Unpublished
V. volvacea	TO AV143	Slovenia	HM246500	HM246486	Unpublished
Volvopluteus asiaticus	TNSF15191	Japan	HM562206	PQ268960	Justo et al. (2011b)
Vp. asiaticus	LE F-332246	Russia	OP862868	OP862870	Kalinina and Malysheva (2023)
Vp. asiaticus	HD2022	China	OP599925	-	Unpublished
Vp. asiaticus	HD2021	China	OP597804	-	Unpublished
Vp. canalipes	UES 10301	Mexico	MW743282	MW743277	Montoya et al. (2021)
Vp. earlei	TO AV133	Italy	HM246496	HM246480	Justo et al. (2011b)
Vp. deliciosus	GDGM73195	China	MK944281	MN056508	Li et al. (2025a)
Vp. deliciosus	GDGM74751	China	MK944280	MN056509	Li et al. (2025a)
Vp. earlei	LAH35715	Pakistan	MW362280	-	Unpublished
Vp. earlei	OKA TR654	Turkey	MW033394	MW029825	Unpublished
Vp. earlei	Mamet7	Democratic Republic of Congo	HM562205	MK278661	Justo et al. (2011b)
Vp. earlei	MA22816	Spain	HM562204	-	Justo et al. (2011a)
Vp. earlei	F14/10	Australia	OP809557	-	Unpublished
Vp. earlei	F86/11	Australia	OP809558	-	Unpublished
Vp. fibrillobrunneus	**CAL 2385 T**	**India**	**PX764988**	**PX764992**	**This study**
Vp. fibrillobrunneus	**CAL 2386**	**India**	**PX764989**	**PX764993**	**This study**
Vp. gloiocephalus	TO AV136	Italy	HM246495	HM246478	Vizzini et al. (2011)
Vp. gloiocephalus	TO AV135	Italy	HM246490	HM246476	Vizzini et al. (2011)
Vp. gloiocephalus	AFTOL-ID 890	USA	DQ494701	-	Matheny et al. (2006)
Vp. gloiocephalus	OKA-TR659	Turkey	MW033399	MW029830	Unpublished
Vp. gloiocephalus	OKA-TR660	Turkey	MW033400	MW029831	Unpublished
Vp. gloiocephalus	OKA TR665	Turkey	MW033405	-	Unpublished
Vp. gloiocephalus	AJ239	Spain	HM562202	MK278662	Justo et al. (2011a)
Vp. gloiocephalus	CM042	Algeria	KP826741	-	Unpublished
Vp. gloiocephalus	LOU18247	Spain	HM562209	-	Justo et al. (2011b)
Vp. gloiocephalus	NLB 1579	Australia	OP809559	-	Unpublished
Vp. gloiocephalus	PBM2272	USA	HM562203	-	Justo et al. (2011a)
Vp. longipes	HKAS135864	China	PQ451543	-	Zhu et al. (2025)
Vp. longipes	HKAS135865	China	PQ451544	-	Zhu et al. (2025)
Vp. longipes	HKAS135863	China	PQ451542	-	Zhu et al. (2025)
Vp. michiganensis	Smith32-590	USA	HM562195	-	Justo et al. (2011a)
Vp. michiganensis	LE 312006	Russia	MK729542	-	Zheng et al. (2025)
Vp. michiganensis	LE 311991	Russia	MK049912	-	Zheng et al. (2025)
Vp. michiganensis	HMJAU-CR106	China	MW242669	-	Zheng et al. (2025)
Vp. michiganensis	UBC F-32158	Canada	MF954699	-	Zheng et al. (2025)
Vp. michiganensis	LE311989	Russia	MK729541	-	Zheng et al. (2025)
Vp. platensis	HKAS135867	China	PQ451546	-	Zhu et al. (2025)
Vp. platensis	HKAS135866	China	PQ451545	-	Zhu et al. (2025)
Vp. yunnanensis	GMB-W1183	China	PQ764862	-	Zheng et al. (2025)
Vp. yunnanensis	GMB-W1187	China	PQ809775	-	Zheng et al. (2025)
Cantharocybe gruberi	AH24539	Spain	JN006422	-	Malysheva et al. (2019)

Notes: The newly generated sequences in this study are in bold black; "T" indicates the holotype specimens, and "-" indicates unavailable sequences.

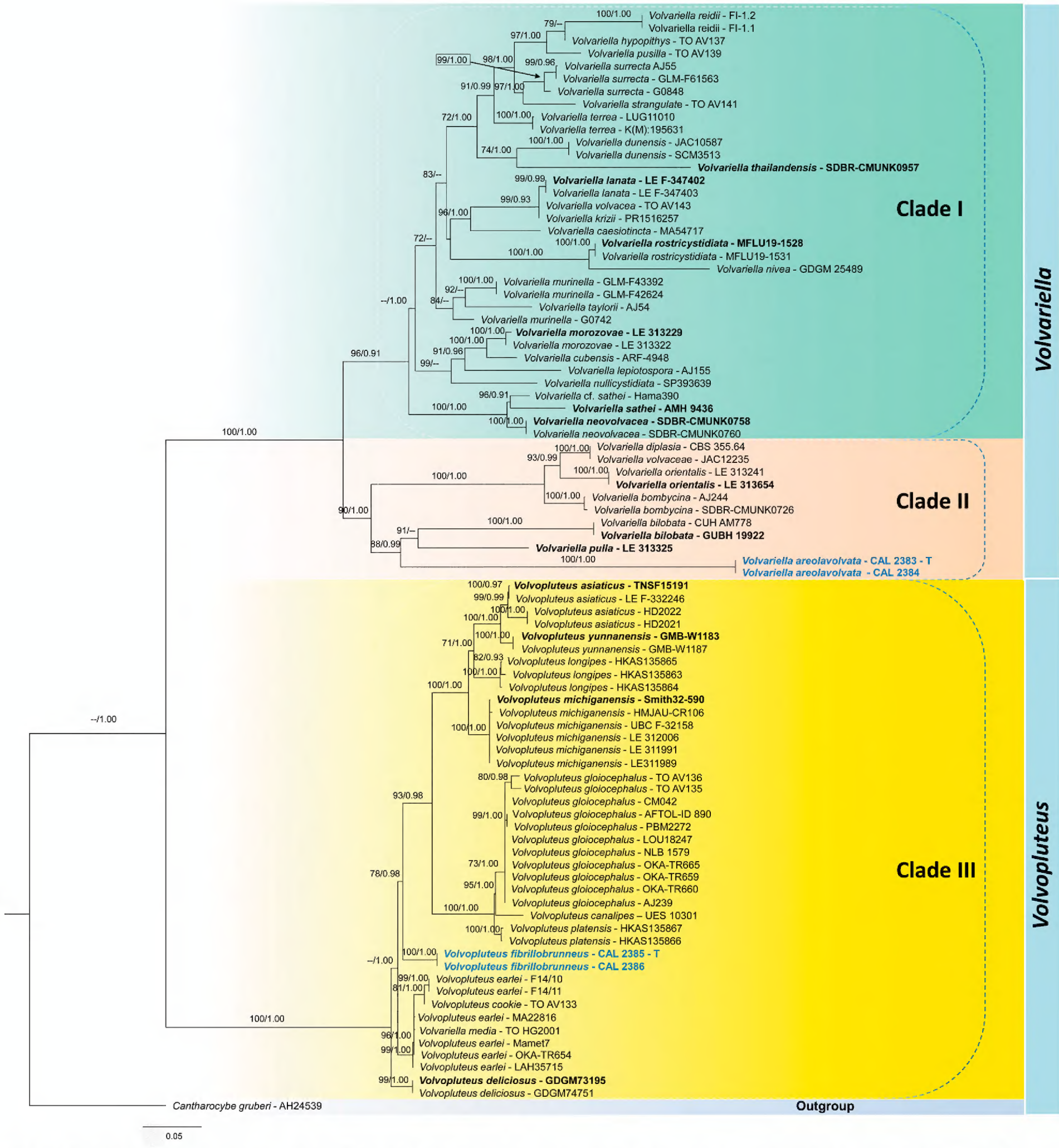
Clade I
Clade II
Clade III
Outgroup
Volvariella
Volvopluteus
Volvariella reidii - FI-1.2
Volvariella reidii - FI-1.1
Volvariella hypopithys - TO AV137
Volvariella pusilla - TO AV139
Volvariella surrecta AJ55
Volvariella surrecta - GLM-F61563
Volvariella surrecta - G0848
Volvariella strangulate - TO AV141
Volvariella terrea - LUG11010
Volvariella terrea - K(M):195631
Volvariella dunensis - JAC10587
Volvariella dunensis - SCM3513
Volvariella thailandensis - SDBR-CMUNK0957
Volvariella lanata - LE F-347402
Volvariella lanata - LE F-347403
Volvariella volvacea - TO AV143
Volvariella krizii - PR1516257
Volvariella caesiotincta - MA54717
Volvariella rostricystidiata - MFLU19-1528
Volvariella rostricystidiata - MFLU19-1531
Volvariella nivea - GDGM 25489
Volvariella murinella - GLM-F43392
Volvariella murinella - GLM-F42624
Volvariella taylorii - AJ54
Volvariella murinella - G0742
Volvariella morozovae - LE 313229
Volvariella morozovae - LE 313322
Volvariella cubensis - ARF-4948
Volvariella lepiotospora - AJ155
Volvariella nullicystidiata - SP393639
Volvariella cf. sathei - Hama390
Volvariella sathei - AMH 9436
Volvariella neovolvacea - SDBR-CMUNK0758
Volvariella neovolvacea - SDBR-CMUNK0760
Volvariella diplasia - CBS 355.64
Volvariella volvaceae - JAC12235
Volvariella orientalis - LE 313241
Volvariella orientalis - LE 313654
Volvariella bombycina - AJ244
Volvariella bombycina - SDBR-CMUNK0726
Volvariella bilobata - CUH AM778
Volvariella bilobata - GUBH 19922
Volvariella pulla - LE 313325
Volvariella areolavolvata - CAL 2383 - T
Volvariella areolavolvata - CAL 2384
Volvopluteus asiaticus - TNSF15191
Volvopluteus asiaticus - LE F-332246
Volvopluteus asiaticus - HD2022
Volvopluteus asiaticus - HD2021
Volvopluteus yunnanensis - GMB-W1183
Volvopluteus yunnanensis - GMB-W1187
Volvopluteus longipes - HKAS135865
Volvopluteus longipes - HKAS135863
Volvopluteus longipes - HKAS135864
Volvopluteus michiganensis - Smith32-590
Volvopluteus michiganensis - HMJAU-CR106
Volvopluteus michiganensis - UBC F-32158
Volvopluteus michiganensis - LE 312006
Volvopluteus michiganensis - LE 311991
Volvopluteus michiganensis - LE311989
Volvopluteus gloiocephalus - TO AV136
Volvopluteus gloiocephalus - TO AV135
Volvopluteus gloiocephalus - CM042
Volvopluteus gloiocephalus - AFTOL-ID 890
Volvopluteus gloiocephalus - PBM2272
Volvopluteus gloiocephalus - LOU18247
Volvopluteus gloiocephalus - NLB 1579
Volvopluteus gloiocephalus - OKA-TR665
Volvopluteus gloiocephalus - OKA-TR659
Volvopluteus gloiocephalus - OKA-TR660
Volvopluteus gloiocephalus - AJ239
Volvopluteus canalipes – UES 10301
Volvopluteus platensis - HKAS135867
Volvopluteus platensis - HKAS135866
Volvopluteus fibrillobrunneus - CAL 2385 - T
Volvopluteus fibrillobrunneus - CAL 2386
Volvopluteus earlei - F14/10
Volvopluteus earlei - F14/11
Volvopluteus cookie - TO AV133
Volvopluteus earlei - MA22816
Volvariella media - TO HG2001
Volvopluteus earlei - Mamet7
Volvopluteus earlei - OKA-TR654
Volvopluteus earlei - LAH35715
Volvopluteus deliciosus - GDGM73195
Volvopluteus deliciosus - GDGM74751
Cantharocybe gruberi - AH24539
0.05

Figure 1. Phylogenetic tree for *Volvariella* and *Volvopluteus* generated from the combined nrITS and nrLSU rDNA sequences using maximum likelihood (−*lnL* = 14452.082637) analysis and Bayesian inference (BI) analyses. Values to the left of '/' are MLBS support, and those to the right of '/' indicate Bayesian posterior probability (PP) support. The MLBS values ≥ 70% and PP values ≥ 0.90 are shown above or below the nodes. The newly generated sequences are shown in bold blue. Voucher numbers for the sequences are indicated in the tree after the taxon name, and other type species are indicated in bold black. 'T' denotes the holotype of the newly sequenced taxa.

Volvariella s.str.

Members of the genus *Volvariella* are subdivided into two distinct clades (Clade I and Clade II), agreeing with Chattopadhyay et al. (2022). Clade I is well supported by the maximum likelihood bootstrap values (96% MLBS) but shows only moderate support in Bayesian posterior probability (0.91 PP) and includes all other

Volvariella species. Clade II comprises taxa that include *V. diplasia*, *V. volvacea*, *V. orientalis*, and *V. bombycina*; in contrast, the remaining species of *V. bilobata*, originally reported from India, and *V. pulla*, recorded from Vietnam, together with the newly proposed species *Volvariella areolavolvata* (CAL 2383), are in this same clade, confirming its systematic position within the genus *Volvariella* (Fig. 1).

Volvopluteus s.str.

Phylogenetic analyses of the genus *Volvopluteus* (Clade III) are also statistically well supported (100% MLBS and 1.00 PP), and this clade includes all representative sequences of *Volvopluteus*, along with those of the newly described Indian taxon *Vp. fibrillobrunneus* (CAL 2385), confirming its systematic position within the genus *Volvopluteus* (Fig. 1). Moreover, *Vp. fibrillobrunneus* is further placed between *Vp. platensis* and *Vp. earlei* in the phylogenetic analysis, with moderate MLBS and strong PP support (78% MLBS/0.98 PP).

Taxonomy

Volvoriella areolavolvata **E. Tarafder, Enjam & A.R. Sherpa., sp. nov.**
Index Fungorum: IF904792
Figs 2, 3

Etymology. The specific epithet "*areolavolvata*" is derived from the Latin aeriolatus (areolate cracking on the outer surface) and refers to the characteristic of the volva.

Diagnosis. *Volvariella areolavolvata* differs from *Volvariella bombycina* by a rigid volva with a distinctive externally areolate, cracked surface that forms pale to dark brown patches, slightly smaller basidiospores (6.8–9.0 × 4.4–5.5 µm), and larger cheilocystidia (63–131 × 21–37 µm).

Holotype. INDIA • West Bengal: North-24-Parganas District, Barasat, Talikhola, 22°44'50.9"N, 88°26'54.7"E, elev. 13.0 m, solitary on dead wood of *Ficus* sp., 07 August 2025, A.R. Sherpa, E. Tarafder & E. Hoque, Sherpa 01/2025 (CAL 2383, holotype).

Description. ***Basidiomata*** medium to large. ***Pileus*** 100–150 mm, fleshy, ovoid to subglobose when young, hemispherical to broadly campanulate, expanding obtusely umbonate; surface dry, sometimes viscid, covered with conspicuous silky fibrils or silky hairs; color white to whitish (10A1), often becoming slightly yellowish (4A5) in the center with age; margin entire. ***Context*** 10 mm thick at the disc, cream white (2A2). ***Lamellae*** free, 15–20 mm broad, crowded with lamellulae of different lengths; white when young, becoming pinkish brown (8A2–4) at maturity; edge concolorous, entire. ***Stipe*** 80–120 × 8–10 mm, central, cylindrical, curved at the base, solid; surface slightly pruinose, white (1A1) creamy, yellowish white (3B3), weakly hairy. ***Volva*** 25–30 mm broad, erect, rigid, thick, and fleshy, irregularly 5–6 lobbed; internally white (1A1), externally cracked areolate pale to dark brown (6F6–8) patches. Odor and taste indistinct.

Basidiospores [30/2/1] (6.8–)7.1–8.7(–9.0) × (4.4–)4.6–5.3(–5.5) µm, [X_{mr} = 7.61–7.92 × 4.85–4.95, X_{mm} = 7.75 ± 0.17 × 4.91 ± 0.33 µm, Q_{mr} = 1.23–1.85, Q_{mm} = 1.56 ± 0.18, n = 30 basidiospores per 2 specimens], oval to ellipsoid, hyaline to light yellowish in 5% KOH, smooth, dextrinoid, thin-walled, and apiculate.

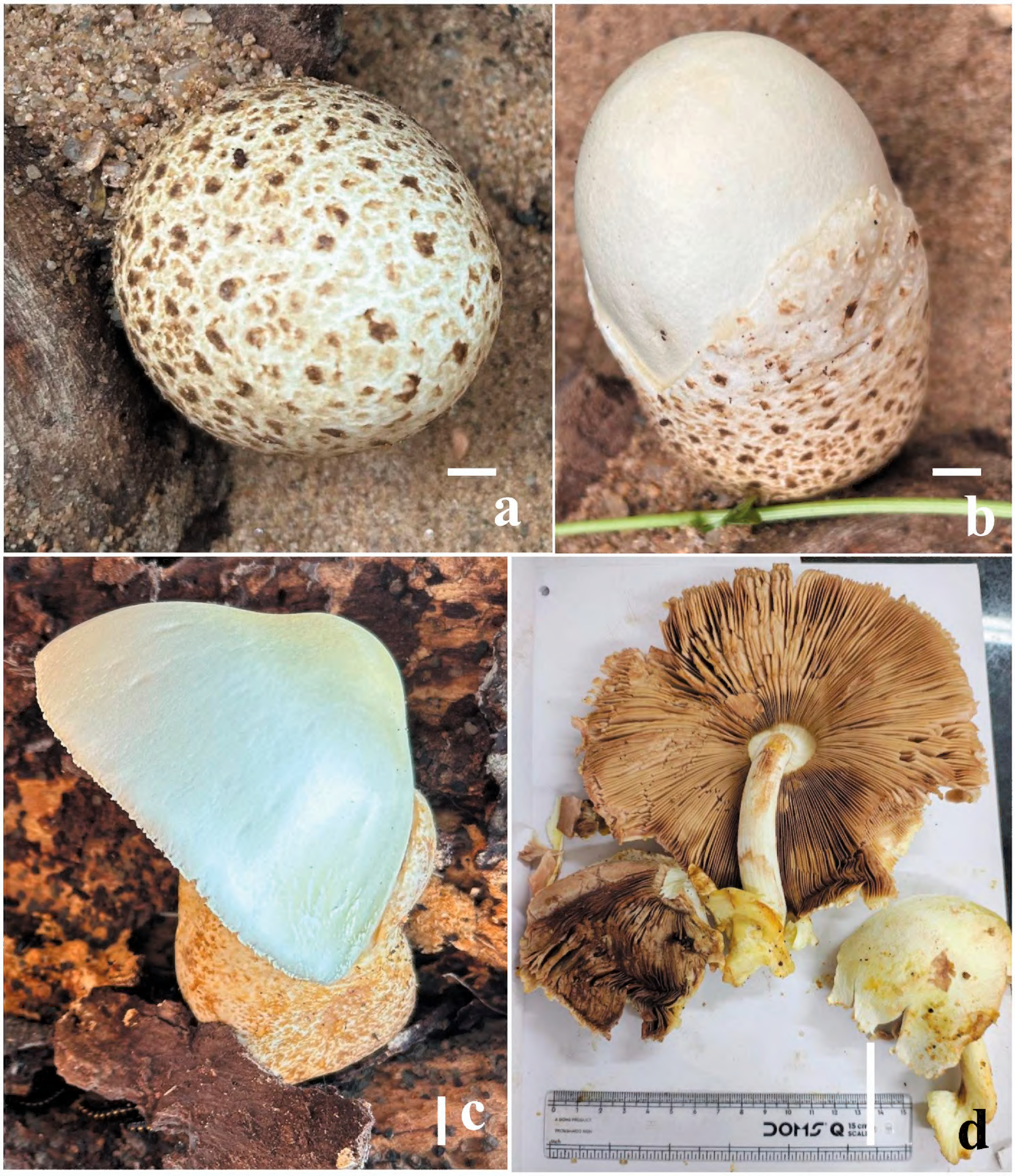

Figure 2. Field photographs of the basidiomata of (**a–d**) *Volvariella areolavolvata* (CAL 2383, holotype). Scale bars: 10 mm (**a–c**); 15 mm (**d**).

Basidia 17.4–26 × 7.4–10 µm, clavate, hyaline in 5% KOH, smooth, with 4 sterigmata, no clamp present at the base. ***Cheilocystidia*** 63–131 × 21–37 µm, hyaline in 5% KOH, thin-walled, mostly lageniform, with a long, narrow neck, forming a sterile layer at the lamellae edge. ***Pleurocystidia*** 44–56 × 13–17 µm, hyaline, thin-walled, broadly clavate with rounded apex or utriform, abundant in lamellae edge. ***Pileipellis*** a cutis made up of 10–37 µm broad, hyaline, thin-walled hyphae, clamp connections absent. ***Stipitipellis*** as compactly arranged

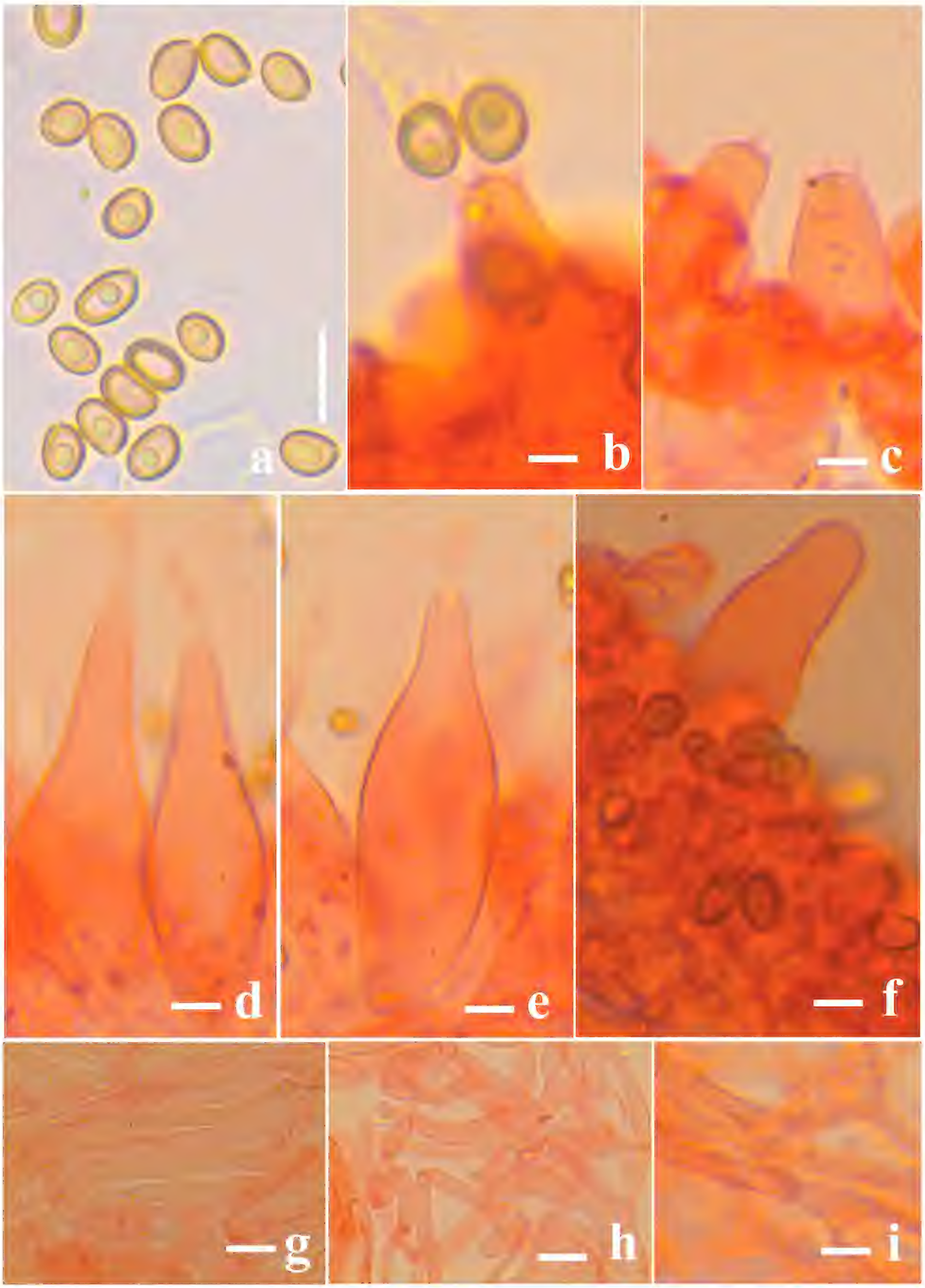

Figure 3. *Volvariella areolavolvata* (CAL 2383, holotype). **a.** Basidiospores; **b, c.** Basidia; **d, e.** Cheilocystidia; **f.** Pleurocystidia; **g.** Pileipellis hyphae; **h.** Stipe hyphae; **i.** Hyphal cells in the volva. Scale bars: 10 µm (**a**); 20 µm (**b–f**); 15 µm (**g–i**).

cutis, 31–52 × 6.7–11.9 µm in diam., thin-walled, septate, clamp connections absent. ***Volva*** composed of septate, thin-walled 5.2–8.3 µm broad hyphae, with clamp connections absent.

Habitat and known distribution. Solitary, on dead wood of *Ficus* sp. So far, it is known only from India.

Additional specimens examined. INDIA • West Bengal: North-24-Parganas district, Barasat, Talikhola, 22°44'50.9"N, 88°26'54.7"E, elev. 13.0 m, 12 August 2025, A.R. Sherpa, E. Tarafder & E. Hoque, Sherpa 02/2025 (CAL 2384, paratype).

GenBank numbers. CAL 2383 (holotype): nrITS = PX776811, nrLSU = PX764990. CAL 2384: nrITS = PX776812, nrLSU = PX764991.

Notes. *Volvariella areolavolvata* is morphologically close to *Volvariella bombycina* but can be distinguished by a combination of macroscopic and microscopic characters. *Volvariella areolavolvata* is characterized by comparatively large basidiomata, a white to creamy pileus lacking squamules, a pure white stipe, and a white volva with brown patches, in combination with medium-sized basidiospores (mean = 7.75 × 4.9 µm). In contrast, *V. bombycina* differs by its robust and stout basidiocarps, a light-colored to pale brownish pileus that is entirely squamulose, a thick stipe, and a large, brown volva (Fig. 2). Moreover, *V. bombycina* has distinctive microscopic characteristics, including relatively small cheilocystidia (50–110 × 10–25 µm; Table 4) with frequently elongated apices.

In our phylogenetic analyses, our collections (CAL 2383 and CAL 2384) clustered closely with *Volvariella pulla* and *Volvariella bilobata* but formed a distinct, well-supported clade (100% MLBS/1.00 PP; Fig. 1). *Volvariella pulla*, originally described from Vietnam (Malysheva et al. 2019), has an ochraceous or grayish brown stipe, an irregularly lobed volva colored dirty grey-brown with rusty brown spots, smaller basidiospores (5.5–8.0 × 4–5 µm vs. 6.8–9.0 × 4.4–5.5 µm), and much larger pleurocystidia (52–83 × 14–34 µm). The Indian collection of *Volvariella bilobata* differs from *V. areolavolvata* by its smaller pileus (45–70 mm diam.), colored grayish to dark brown, bilobed saccate volva, and much smaller basidiospores (4.8–5.5 × 2.7–3.5 µm; Fig. 3) and pleurocystidia (18.5–27.5 × 7–10 µm) (Chattopadhyay et al. 2022). Here, we introduce our collections as a novel species of *V. areolavolvata* based on morpho-molecular analyses.

Volvopluteus fibrillobrunneus **Enjam, E. Tarafder & A.R. Sherpa., sp. nov.**
Index Fungorum: IF904793
Figs 4, 5

Etymology. The specific epithet "*fibrillobrunneus*" refers to the brown color with a fibrillose pileus surface.

Diagnosis. *Volvopluteus fibrillobrunneus* differs from *Volvopluteus earlei* by its fibrillose brown pileus surface with larger basidiocarps (Pileus < 50 mm in diameter *Vp. earlei*) and smaller basidiospores (8.3–11.5 × 5.1–7.1 µm).

Holotype. INDIA • West Bengal: North-24-Parganas district, Barasat, Near Kazibari Bus Stand, 22°44'45.5"N, 88°26'41.9"E, elev. 13.0 m, Scattered on the soil around with rich humus in broad-leaved forest, 18 September 2024, E. Hoque, AE-37/2024 (CAL 2385, holotype).

Description. ***Basidiomata*** medium to large. ***Pileus*** 80–97 mm diam., plano-convex to plane with age, low umbo at center, not viscid, dry, glabrous, innately radially fibrillose, striate, surface light brown (6D4), grayish brown (6D3) with grey (5B2) when young, dark blonde (5D4) center and birch grey (5C2) sides after maturity, becoming lighter grayish brown (5F3–5E4) towards the margin and yellowish brown (5B2–5C4) after dried; margin striate, radially fibrillose, slightly cracked with maturity, cream whitish squamulose present. ***Context*** 4 mm broad, white to grayish white (2B1). ***Lamellae*** free, approximately 10 mm broad, close to crowded, pinkish white (8A3–8B3), brownish gray (11C2) at maturity. ***Stipe*** 120–140 × 10–14 mm, central, cylindrical, solid, white, glabrous, not viscid, when young visibly broadening towards the base and in maturity with bulbous base enclosed in sac-like volva. ***Volva*** 15–19 × 8–10 mm, free from the stipe, saccate, membranous, 2–3 lobed, with a white to light brownish outer surface and whitish inner surface. Odor and taste indistinct.

Basidiospores (8.3–)8.5–9.6(–11.5) × (5.1–)5.4–6.3(–7.1) µm, [X_{mr} = 8.65–9.43 × 5.88–6.25, X_{mm} = 9.85 ± 0.92 × 6.30 ± 0.49 µm, Q_{mr} = 1.36–1.75, Q_{mm} = 1.57 ± 0.19, n = 30 basidiospores per 2 specimens], ellipsoid to elongate, smooth, hyaline to light yellowish in 5% KOH, thin-walled, and apiculate. ***Basidia*** 25.7–45.6 × 9.8–11.9 µm, clavate, hyaline in 5% KOH, smooth, with 2–4 prominent sterigmata, no clamp at base. ***Cheilocystidia*** 34–72 × 15–29 µm, hyaline in 5% KOH, thick-walled, mostly clavate, forming a sterile layer at the lamellae edge. ***Pleurocystidia*** 53–75 × 14–21 µm, hyaline, thin-walled, lageniform rostrate with apical appendages. ***Pileipellis*** ixocutis, made up of hyphae 25–32 µm broad, hyaline, thin-walled, clamp connections absent. ***Stipitipellis*** as compactly arranged hyphae, 23–38 µm broad, thin-walled, clamp connections absent. ***Volva*** composed of septate interwoven cylindrical hyphae, thin-walled 9–13 µm broad, clamp connection absent.

Habitat and known distribution. Scattered on the soil around with rich humus in a broad-leaved forest. So far, it is only known from India.

Additional specimens examined. INDIA • West Bengal: North-24-Parganas district, Barasat, near Kazibari Bus Stand, 22°44'45.5"N, 88°26'41.9"E, elev. 13.0 m, scattered on the soil around with rich humus in broad-leaved forest, 21 September 2024, E. Hoque, AE-41/2024 (CAL 2386, paratype).

GenBank numbers. CAL 2385 (holotype): nrITS = PX764988, nrLSU = PX764992; CAL 2386: nrITS = PX764989, nrLSU = PX764993.

Notes. *Volvopluteus fibrillobrunneus* is characterized by a medium- to moderately large-sized (80–97 mm) pileus, entirely light brown to grayish brown, with a radially fibrillose surface; close to crowded lamellae colored pinkish white to brownish gray; a multi-lobed saccate volva with a white to light brownish outer surface and a whitish inner surface (Fig. 4); larger basidiospores measuring 8.3–11.5 × 5.1–7.1 µm; clavate to ventricose cheilocystidia measuring 34–72 × 15–29 µm; lageniform rostrate pleurocystidia with apical appendages measuring 53–75 × 14–21 µm; and habitat on rich humus soil (Fig. 5). Among macro-morphologically similar taxa (Table 5), *Vp. earlei* can be distinguished by its smaller basidiospores (11–16 × 8–11 µm), the presence of longer pleurocystidia (up to 110 µm), and the presence of cheilocystidia (Shaffer 1962; Justo and Castro 2010; Giannoni et al. 2018). Moreover, *Volvopluteus earlei* was originally described from Cuba (Murrill 1911) and later reported from the USA (Coker 1947), Mexico (Vázquez et al. 1989), Africa (Heinemann 1975), Argentina (Niveiro and

Figure 4. Field photographs of the basidiomata of (**a–c**) *Volvopluteus fibrillobrunneus* (CAL 2385, holotype) in natural habitat. Scale bars: 10 mm (**a–c**).

Albertó 2012), Italy (Contu 2006; Giannoni et al. 2018), Spain (Justo and Castro 2010), Turkey (Kaygusuz et al. 2021), and India (Chouhan and Panwar 2021).

In the phylogenetic analyses (Fig. 1), *Vp. fibrillobrunneus* is placed as a sister group to *Vp. platensis*, originally described from China (Zhu et al. 2025), and can be distinguished from *Vp. fibrillobrunneus* by the smaller basidiomata (48–70 mm broad in *Vp. platensis*), a slightly brownish to grayish white pileus, and clavate to fusoid cheilocystidia (Zhu et al. 2025). Hence, here we introduce our collections as a novel species of *Volvopluteus s.str.*, i.e., *Vp. fibrillobrunneus*, based on morpho-molecular analyses.

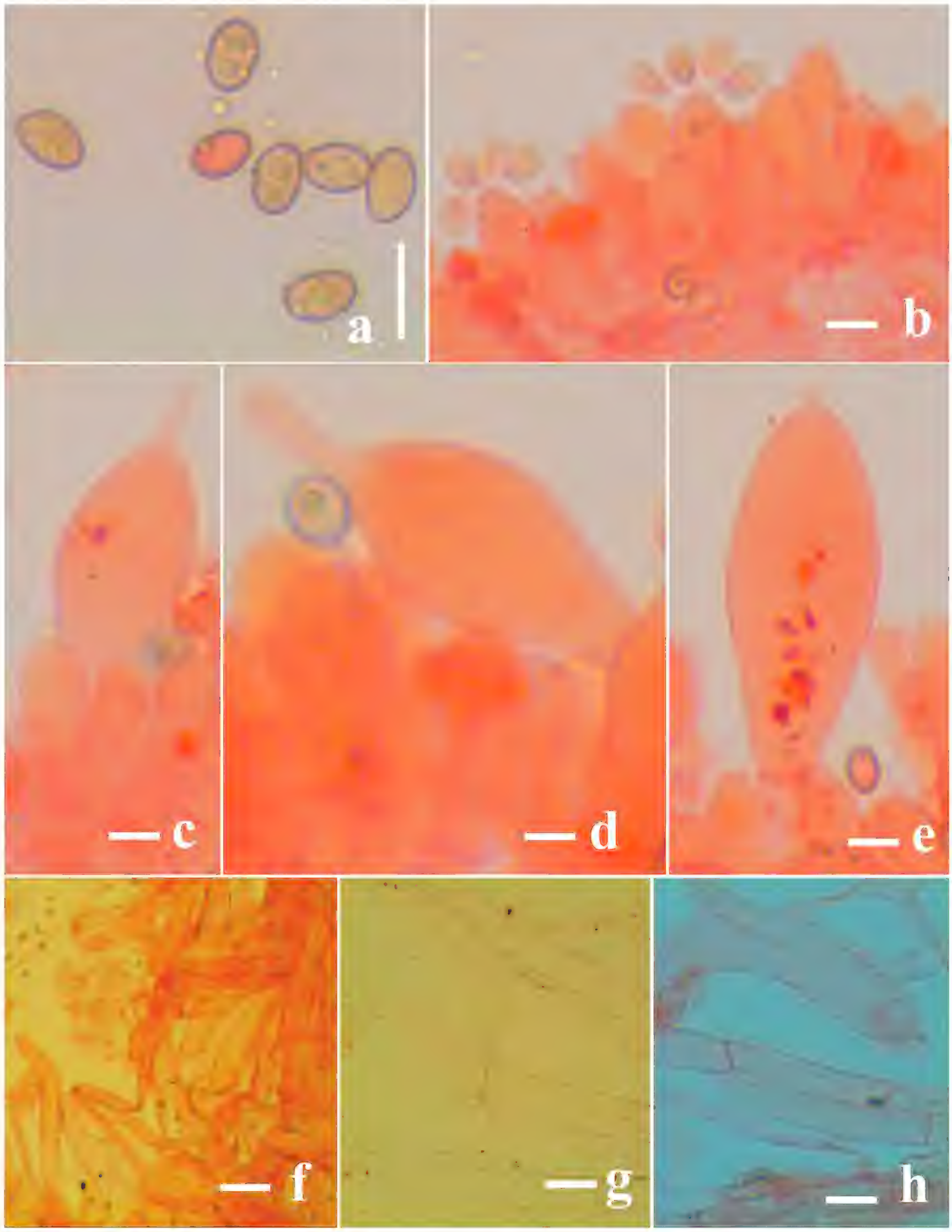

Figure 5. *Volvopluteus fibrillobrunneus* (CAL 2385, holotype). **a.** Basidiospores; **b.** Basidia; **c, d.** Cheilocystidia; **e.** Pleurocystidia; **f.** Pileipellis hyphae; **g.** Stipe hyphae; **h.** Hyphal cells in the volva. Scale bars: 10 µm (**a**); 20 µm (**b–e**); 15 µm (**f–i**).

Discussion

Geographically, West Bengal is located in eastern India and is bordered by the high Himalayan peaks in the north, coastal ecosystems in the south, and the Gangetic delta and plateaus in between (Tarafder et al. 2023). Subtropical broadleaved to subalpine forests dominate in the Himalayan region; in contrast,

littoral and swamp forests cover the coastal regions, and dry deciduous forests prevail on the plateaus and in the Gangetic plains (Dutta et al. 2015). This wide range of phyto-topographical features, together with altitudinal and climatic variations, creates ample opportunities for the luxuriant growth of macrofungi. Although several species of *Volvariella* have been reported from West Bengal, India, most earlier studies were based solely on morphological characterization, viz., *Volvariella castanea* (Massee) G.C. Rath (Calcutta, Massee 1912), *V. delicatula* (Massee) Manjula (Calcutta, Massee 1912), *V. diplasia* (Berk. & Broome) Singer (Hooghly and Bose 1920a), *V. pusilla* (Pers.) Singer (South 24-Parganas 'fide' Dutta et al. 2011, 2013), *V. terastia* (Berk. & Broome) Singer (Berk. & Broome) Singer (Calcutta, Bose 1920b, 1921), *V. thwaitesii* (Hook. f. ex Berk.) G.C. Rath (Darjeeling, Berkeley 1850), and *V. volvacea* (Bull.) Singer (South 24-Parganas 'fide' Dutta et al. 2011, 2013).

Volvariella areolavolvata was characterized by a large-sized (100–150 mm), entirely white pileus with a slightly silky hairy surface, often becoming slightly yellowish in the center with age; crowded lamellae colored pinkish white to grayish brown; a volva that is rigid, thick, and fleshy, irregularly lobed, internally white, and externally cracked, with areolate pale to dark brown patches; smaller basidiospores (6.8–9.0 × 4.4–5.5 µm); mostly lageniform cheilocystidia (63–131 × 21–37 µm); broadly clavate with a rounded apex or utriform pleurocystidia (44–56 × 13–17 µm; Table 4); and habitat on dead wood. In our phylogenetic analyses, *V. areolavolvata* clustered closely with *V. pulla* and *V. bilobata*, forming a distinct and well-supported clade (100% MLBS/1.00 PP; Fig. 1).

Additionally, *Vp. fibrillobrunneus* falls between *Vp. platensis* and *Vp. earlei* in the phylogenetic analysis, with moderate MLBS and strong PP support (78% MLBS/0.98 PP). However, *Volvopluteus fibrillobrunneus* was characterized by a medium- to moderately large-sized (80–97 mm), entirely light brown to grayish brown pileus with a radially fibrillose surface; close to crowded lamellae colored pinkish white to brownish gray; a multi-lobed saccate volva with a white to light brownish outer surface and a whitish inner surface; larger basidiospores (8.3–11.5 × 5.1–7.1 µm); clavate to ventricose cheilocystidia (34–72 × 15–29 µm); and lageniform pleurocystidia (55–60 × 29–47 µm). Among macro-morphologically similar taxa (Table 5), *Vp. earlei* can be distinguished by its smaller basidiospores (11–16 × 8–11 µm) and the presence of longer pleurocystidia (up to 110 µm). In

Table 4. Comparison of *Volvariella areolavolvata* (CAL 2383) with its closely related taxa.

Name of the taxon	Pileus color	Pileus diameter (mm)	Stipe (mm)	Basidiospore (µm)	Basidia (µm)	Pleurocystidia (µm)	Cheilocystidia (µm)	Reference
Volvariella areolavolvata	**White to whitish, often becoming slightly yellowish in the center**	**100–150**	**80–120 × 8–10**	**6.8–9.0 × 4.4–5.5; Q = 1.23–1.85**	**17.4–26 × 7.4–10**	**44–56 × 13–17**	**63–131 × 21–37**	**This study**
V. bombycina	Whitish to pale ochraceous	70–190	70–190 × 7–20	6.5–9.5 × 4.0–6.5; Q = 1.20–1.70	20–30 × 8–11	40–100 × 10–20	50–110 × 10–25	Singer and Digilio (1951)
V. biolobata	Entirely grayish brown pileus	45–70	45–60 × 4–10	4.8–5.5 × 2.7–3.5; Q = 1.57–1.60	20–23 × 5–7	18.5–27.5 × 7–10	32–83 × 13–30	Chattopadhyay et al. (2022)
V. pulla	Pileus grayish brown or ash brown	40–75	55–70 × 3–5	5.5–7.0 × 4.0–5.0; Q = 1.20–1.59	15–22 × 7–8	52–83 × 14–34	45–75 × 14–23	Malysheva et al. (2019)

Table 5. Comparison of *Volvopluteus fibrillobrunneus* (CAL 2385) and its closely related taxa. Abbreviations: NR = not reported.

Name of the taxon	Pileus color	Pileus diameter (mm)	Stipe (mm)	Basidiospore (µm)	Basidia (µm)	Pleurocystidia (µm)	Cheilocystidia (µm)	Reference
Volvopluteus fibrillobrunneus	**Light brown to gaeyish brown when young, dark blonde center and birch grey sides after maturity**	**80–97**	**120–140 × 10–14**	**8.3–11.5 × 5.1–7.1**	**25.7–45.6 × 9.8–11.9**	**53–75 × 14–21**	**34–72 × 15–29**	**This study**
Vp. earlei	White or ochraceous buff, light ochraceous at center	25–45	35–65 × 3–7	11.0–16.0 × 7–9.5	30–47 × 10–18	47–98 × 14–20	25–50 × 10–35	Montoya et al. (2021)
Vp. deliciosus	Surface usually grayish	50–110	80–140 × 8–27	12.5–16.5 × 7.5–10	42–65 × 13–16	62–88 × 12–33	50–65 × 18–32	Li et al. (2025a)
Vp. diversisporus	Surface orange white	41–59	36–85 × 4–6	11.2–16.0 × 7.2–14.4	25.6–46.4 × 9.6–17.6	20.8–86.4 × 8.8–34.0	32.0–80.0 × 9.6–40.0	Kaur and Singh (2014)
Vp. earlei	Slightly darker or pale yellowish biscuit in center	20–50	40–70 × 5–10	12–15.5 × 7.3–9.5	35–51 × 10–14	31–85 × 15–38	30–75 × 11–24	Bougher and Barrett (2023)
Vp. gloiocephalus	Uniformly grayish beige except darker brownish at the umbo	30–110	35–120 × 5–22	12–17.5 × 7.5–10	42–56 × 12–16	45–60 × 20–40	32–70 × 10–25	Bougher and Barrett (2023)
Vp. longipes	Slightly brownish at center, grayish white to dirty white	48–70	130–150 × 4–10	14–20 × 8–11	35–60 × 16–23	NR	40–75 × 16–29	Zhu et al. (2025)
Vp. michiganensis	Gray to brownish gray	70–90	80–110 × 10–15	10.5–13.5 × 6.5–8	35–55 × 10–15	70–110 × 25–45	60–75 × 15–27	Justo et al. (2011a)
Vp. platensis	Grayish white to dirty white, sometimes with a cream tinge	30–45	50–80 × 4–10	15.5–20 × 9–12	35–68 × 15–20	65–95 × 18–40	NR	Zhu et al. (2025)
Vp. shafferii	Surface grayish orange, orange grey at center, with pinkish tinge towards margin	10–112	70–165 × 18–25	11.2–16 × 7.2–12.8	17.6–34.0 × 8.9–16.0	NR	NR	Kaur and Singh (2014)
Vp. striatellus	Pale grey when young, transitioning to white with grayish tints at maturity	48–80	110–160 × 5–23	15.5–18.8 × 9.6–11.5	40.8–55 × 15.1–19.9	62–113.8 × 24.5–48.5	50.1–81.5 × 24.1–34.9	Li et al. (2025b)
Vp. yunnanensis	Dark blonde center and birch grey sides	59–85	120–137 × 11–13	11.3–12.9 × 6.0–6.9	43–54 × 10–15	60–82 × 16–25	60–86 × 14–27	Zheng et al. (2025)

the phylogenetic tree for the combined dataset (Fig. 1), our newly described taxon is also close to *Vp. platensis*, which was initially described by relatively small basidiomata, with pileus diameters not exceeding 45 mm, a slightly brownish to grayish white pileus, and clavate to fusoid cheilocystidia (Zhu et al. 2025).

The discovery of *V. areolavolvata* and *Vp. fibrillobrunneus* increases our understanding of the diversity and distribution of these genera in eastern India. In conclusion, *V. areolavolvata* and *Vp. fibrillobrunneus* are supported by both

morphological and phylogenetic analyses. Moreover, their discovery significantly advances the understanding of agaric diversity in eastern India and underscores the need for continued exploration and integrative taxonomic studies, given modern phylogenetic analyses in the region.

Acknowledgements

Shaun Pennycook is thanked for his suggestions on the Latin name.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Use of AI

No use of AI was reported.

Funding

This research was funded by the National Natural Science Foundation of China (No. NSFC 32460002, 32260004), the Yunnan Province Young and Middle-Aged Academic and Technical Leaders Reserve Talents Program (Grant No. 202305AC350252), the Yunnan Revitalization Talents Support Plan (Young Talents Program and High-End Foreign Experts Program), and the Key Laboratory of the Yunnan Provincial Department of Education of the Deep-Time Evolution on Biodiversity from the Origin of the Pearl River.

Author contributions

Conceptualization: ET, EH, ARS; Data curation: ET, EH, ARS; Formal analysis: ET, EH, SCK; Investigation: ET, EH; Methodology: ET, EH, ARS, SCK, NNW; Project administration and resources: ET, ARS; Software: ET, SCK, EH, NNW, ARS; Supervision: DDQ, WW; Writing—original draft: ET, EH; Writing—review and editing: ET, ARS, SCK, NNW, QL, WW, DDQ; Funding acquisition: DDQ, WW. The first draft of the manuscript was written by ET and EH, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Author ORCIDs

Entaj Tarafder https://orcid.org/0000-0002-3680-3433
Enjamul Hoque https://orcid.org/0009-0004-3518-4839
Ang Rinzing Sherpa https://orcid.org/0000-0003-1488-3513
Samantha C. Karunarathna https://orcid.org/0000-0001-7080-0781
Meimei Wang https://orcid.org/0000-0003-3747-5432
Nalin N. Wijayawardene https://orcid.org/0000-0003-0522-5498
Qiang Li https://orcid.org/0000-0002-9735-8214
Fuqiang Yu https://orcid.org/0000-0001-7931-080X
Dong-Qin Dai https://orcid.org/0000-0001-8935-8807
Wannapawn Watsuntorn https://orcid.org/0009-0002-3196-4753

Data availability

Sequence data generated for the present study have been deposited in GenBank. The accession numbers are as follows: CAL 2383 (nrITS: PX776811; nrLSU: PX764990); CAL 2384 (nrITS: PX776812; nrLSU: PX764991); CAL 2385 (nrITS: PX764988; nrLSU: PX764992); CAL 2386 (nrITS: PX764989; nrLSU: PX764993). The data can be accessed at https://www.ncbi.nlm.nih.gov/genbank/. All data that support the findings of this study are available in the main text.

References

Basumatary M, Gogoi M (2016) Uses of wild edible macro fungi by Bodo community of Kokrajhar district, Assam, India. Tropical Plant Research 3(2): 176–181.

Berkeley MJ (1850) Decades XXV to XXX. Sikkim Himalayan fungi, collected by Dr J.D. Hooker. Hooker's Journal of Botany and Kew Gardens Miscellany 2: 42–51, 76–88, 106–112.

Boekhout T (1990) *Volvariella*. In: Bas C, Kuyper ThW, Noordeloos ME, Vellinga EC (Eds) Flora Agaricina Neerlandica. AA Balkema, Rotterdam, The Netherlands, 56–64.

Bose SR (1920a) Records of Agaricaceae from Bengal. Journal of the Asiatic Society of Bengal 16: 347–354.

Bose SR (1920b) Description of fungi from Bengal. Proceedings of the Indian Association for the Cultivation of Science (for the year 1918): 136–143.

Bose SR (1921) Possibilities of mushroom industry in India by cultivation. Indian Agriculture Journal 16: 643–647.

Bougher NL, Barrett MD (2023) *Volvopluteus earlei* and *Volvariella taylorii*: new fungi for Western Australia (Basidiomycota: Agaricales: Pluteaceae). Nuytsia 34: 187–201. https://doi.org/10.58828/nuy01054

Chattopadhyay P, Talukdar M, Beypih J, Tayung K, Dutta AK (2022) A new species of *Volvariella* (Agaricales, Basidiomycota) from West Bengal, India. Phytotaxa 567(1): 36–48. https://doi.org/10.11646/phytotaxa.567.1.3

Chouhan R, Panwar C (2021) The genus *Volvariella* from Mount Abu, Rajasthan, India. Journal of Mycopathological Research 59: 63–66.

Coker WC (1947) North Carolina species of Volvaria. Journal of the Elisha Mitchell Scientific Society 63: 220–230.

Contu M (2006) *Volvariella earlei* (Basidiomycota, Pluteaceae) nuova per l'Europa, e note sulla tassonomia di *Volvariella media sensu* J. Lange. Micologia e Vegetazione Mediterranea 21(2): 101–106. [in Italian]

Crous PW, Wingfield MJ, Burgess TI, Carnegie AJ, Hardy G, Smith D, Summerell BA, Cano-Lira JF, Guarro J, Houbraken J, Lombard L, Martin MP, Sandoval-Denis M, Alexandrova AV, Barnes CW, Baseia IG, Bezerra JDP, Guarnaccia V, May TW, Hernandez-Restrepo M, Stchigel AM, Miller AN, Ordonez ME, Abreu VP, Accioly T, Agnello C, Agustin Colman A, Albuquerque CC, Alfredo DS, Alvarado P, Araujo-Magalhaes GR, Arauzo S, Atkinson T, Barili A, Barreto RW, Bezerra JL, Cabral TS, Camello Rodriguez F, Cruz R, Daniels PP, da Silva BDB, de Almeida DAC, de Carvalho Jr AA, Decock CA, Delgat L, Denman S, Dimitrov RA, Edwards J, Fedosova AG, Ferreira RJ, Firmino AL, Flores JA, Garcia D, Gene J, Giraldo A, Gois JS, Gomes AAM, Goncalves CM, Gouliamova DE, Groenewald M, Gueorguiev BV, Guevara Suarez M, Gusmao LFP, Hosaka K, Hubka V, Huhndorf SM, Jadan M, Jurjevic Z, Kraak B, Kucera V, Kumar TKA, Kusan I, Lacerda SR, Lamlertthon S, Lisboa WS, Loizides M, Luangsa-Ard JJ, Lyskova P, Mac Cormack WP, Macedo DM, Machado AR, Malysheva EF, Marinho P, Matocec N, Meijer M, Mesic A, Mongkolsamrit S, Moreira KA, Morozova OV, Nair KU, Nakamura N, Noisripoom W, Olariaga I, Oliveira RJV, Paiva

LM, Pawar P, Pereira OL, Peterson SW, Prieto M, Rodriguez-Andrade E, Rojo De Blas C, Roy M, Santos ES, Sharma R, Silva GA, Souza-Motta CM, Takeuchi-Kaneko Y, Tanaka C, Thakur A, Smith MT, Tkalcec Z, Valenzuela-Lopez N, van der Kleij P, Verbeken A, Viana MG, Wang XW, Groenewald JZ (2017) Fungal Planet description sheets: 625–715. Persoonia 39: 270–467. https://doi.org/10.3767/persoonia.2017.39.11

Daniëls PP, Hama O, Fernández A, García-Pantaleón FI, Baragé M, Ibrahim D, Alcántara MR (2015) First records of some Asian macromycetes in Africa. Mycotaxon 130(2): 337–359. https://doi.org/10.5248/130.337

Darriba D, Taboada GL, Doallo R, Posada D (2012) jModelTest 2: More models, new heuristics and parallel computing. Nature Methods 9(8): 772. https://doi.org/10.1038/nmeth.2109

Debnath S, Upadhyay RC, Saha R, Majumdar K, Das P, Saha AK (2020) A checklist of macrofungi (mushroom) diversity and distribution in the forests of Tripura, India. Journal of Threatened Taxa 12: 16314–16346. https://doi.org/10.11609/jott.5730.12.10.16314-16346

Dutta AK, Pradhan P, Roy A, Acharya K (2011) *Volvariella* of West Bengal, India I. Researcher 3(5): 13–17.

Dutta AK, Pradhan P, Basu SK, Acharya K (2013) Macrofungal diversity and ecology of the mangrove ecosystem in the Indian part of Sundarbans. Biodiversity (Nepean) 14(4): 196–206. https://doi.org/10.1080/14888386.2013.848824

Dutta AK, Paloi S, Pradhan P, Acharya K (2015) A new species of *Russula* (Russulaceae) from India based on morphological and molecular (ITS sequence) data. Turkish Journal of Botany 39: 850–856. https://doi.org/10.3906/bot-1407-1

Dutta AK, Nandi S, Tarafder E, Sikder R, Roy A, Acharya K (2017) *Trogia benghalensis* (Marasmiaceae, Basidiomycota), a new species from India. Phytotaxa 331(2): 257–266. https://doi.org/10.11646/phytotaxa.331.2.11

Florence EJM (2004) Biodiversity documentation for Kerala, Part 2: Microorganisms (Fungi). KFRI Handbook No. 17. Kerala Forest Research Institute, Peechi, Kerala, India.

Gardes M, Bruns TD (1993) ITS primers with enhanced specificity for basidiomycetes—Application to the identification of mycorrhizae and rusts. Molecular Ecology 2: 113–118. https://doi.org/10.1111/j.1365-294X.1993.tb00005.x

Geyer CJ (1991) Markov chain Monte Carlo maximum likelihood. In: Keramidas EM (Ed.) Computing Science and Statistics: Proceedings of the 23rd Symposium on the Interface. Interface Foundation, Fairfax Station, 156–163.

Giannoni F, Pera U, Maggiora MD (2018) *Volvopluteus earlei*, an uncommon species throughout Europe, new for Tuscany. Micologia Toscana 0: 11–25.

Gogoi G, Prakash V (2015) Diversity of gasteroid fungi (Basidiomycota) in Hollongapar Gibbon Wildlife Sanctuary, Jorhat, Assam, India. Current Research in Environmental & Applied Mycology 5(3): 202–212. https://doi.org/10.5943/cream/5/3/5

Heinemann P (1975) Flore illustrée des champignons d'Afrique centrale. Vol. 4: *Volvariella*. National Botanic Garden of Belgium, Meise, Brussels. [in French]

Hall TA (1999) BioEdit: A user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. Nucleic Acids Symposium Series 41: 95–98.

Hu Y, Karunarathna SC, Li H, Galappaththi MC, Zhao CL, Kakumyan P, Mortimer PE (2022) The impact of drying temperature on basidiospore size. Diversity 14(4): 239. https://doi.org/10.3390/d14040239

Hussain S, Al-Kharousi M, Al-Maqbali D, Al-Owaisi AA, Velazhahan R, Al-Sadi AM, Al-Yahya'ei MN (2025) Phylogeny of the genus *Volvariella* with the description of one new species and two new records from Oman. Fungal Systematics and Evolution 16(1): 29–40. https://doi.org/10.3114/fuse.2025.16.2

Justo A, Castro ML (2010) An annotated checklist of *Volvariella* in the Iberian Peninsula and Balearic Islands. Mycotaxon 112: 271–273. https://doi.org/10.5248/112.271

Justo A, Vizzini A, Minnis AM, Menolli Jr N, Capelari M, Rodríguez O, Malysheva E, Contu M, Ghignone S, Hibbett DS (2011a) Phylogeny of the Pluteaceae (Agaricales, Basidiomycota): Taxonomy and character evolution. Fungal Biology 115: 1–20. https://doi.org/10.1016/j.funbio.2010.09.012

Justo A, Minnis AM, Ghignone S, Menolli Jr N, Capelari M, Rodríguez O, Malysheva E, Contu M, Vizzini A (2011b) Species recognition in *Pluteus* and *Volvopluteus* (Pluteaceae, Agaricales): Morphology, geography and phylogeny. Mycological Progress 10: 453–479. https://doi.org/10.1007/s11557-010-0716-z

Kalichman J, Kirk PM, Matheny PB (2020) A compendium of generic names of agarics and Agaricales. Taxon 69: 425–447. https://doi.org/10.1002/tax.12240

Kalinina LB, Malysheva EF (2023) *Volvopluteus asiaticus* (Agaricales, Basidiomycota): The second finding in the world. Turczaninowia 26: 39–44. https://doi.org/10.14258/turczaninowia.26.2.2

Katoh K, Standley DM (2016) A simple method to control over-alignment in the MAFFT multiple sequence alignment program. Bioinformatics (Oxford, England) 32: 1933–1942. https://doi.org/10.1093/bioinformatics/btw108

Katoh K, Rozewicki J, Yamada K (2019) MAFFT online service: Multiple sequence alignment, interactive sequence choice and visualization. Briefings in Bioinformatics 20: 1160–1166. https://doi.org/10.1093/bib/bbx108

Kaur M, Singh Y (2014) Family Pluteaceae in North West India. In: Singh M (Ed.) Proceedings of the 8th International Conference on Mushroom Biology and Mushroom Products (ICMBMP8), New Delhi, India, 19–22 November 2014. Yugantar Prakashan Private Limited, Solan, India, 55–70.

Kaur NJ, Saini MK, Kaur H (2013) Two new species of agarics from India. Mycosphere: Journal of Fungal Biology 4: 856–863. https://doi.org/10.5943/mycosphere/4/5/1

Kaygusuz O, Knudsen H, Türkekul İ, Çolak OF (2020) *Volvariella turcica*, a new species from Turkey, and a multigene phylogeny of *Volvariella*. Mycologia 112(3): 577–587. https://doi.org/10.1080/00275514.2020.1724048

Kaygusuz O, Türkekul İ, Knudsen H, Menolli Jr N (2021) *Volvopluteus* and *Pluteus* section *Pluteus* (Agaricales, Pluteaceae) in Turkey based on morphological and molecular data. Turkish Journal of Botany 45: 224–242. https://doi.org/10.3906/bot-2012-7

Kornerup A, Wanscher JH (1978) Methuen handbook of colour. 3rd edn. Eyre Methuen, London, 1–252.

Kumla J, Suwannarach N, Wannathes N, Lumyong S (2022) Survey of *Volvariella* (Agaricales, Basidiomycota) including two new species, *V. neovolvacea* and *V. thailandensis*, from northern Thailand. Diversity 14: 161. https://doi.org/10.3390/d14030161

Lakshmanan L, Bhavanidevi S, Nair MC (1979) Occurrence of *Thanatephorus cucumeris* as a weed fungus on mushroom beds. Current Science 48(12): 543–544.

Lalrinawmi H (2019) Study on soil mushrooms in Aizawl District of Mizoram, India. MSc Thesis, Mizoram University, India, 176 pp.

Largent DL, Johnson D, Watling R (1977) How to identify mushrooms to genus, III: microscopic features. Mad River Press, Eureka, California, 148 pp.

Larsson A (2014) AliView: A fast and lightweight alignment viewer and editor for large data sets. Bioinformatics (Oxford, England) 30(22): 3276–3278. https://doi.org/10.1093/bioinformatics/btu531

Li TH, Chen XL, Shen YH, Li T (2009) A white species of *Volvariella* (Basidiomycota, Agaricales) from southern China. Mycotaxon 109: 255–262. https://doi.org/10.5248/109.255

Li CH, Zhang M, Li JP, Li TH (2025a) *Volvopluteus deliciosus* sp. nov. (Pluteaceae, Agaricales), a new edible species from Xinjiang, China. Phytotaxa 683: 253–262. https://doi.org/10.11646/phytotaxa.683.3.6

Li JH, Fu HY, Fan L (2025b) *Volvopluteus striatellus* (Pluteaceae, Agaricales), a novel species from North China. Phytotaxa 736(1): 79–87. https://doi.org/10.11646/phytotaxa.736.1.7

Lu WH, Nutaratat P, Kumla J, Tibpromma S, Elgorban AM, Karunarathna SC, Suwannarach N (2024) Morphological and molecular identification of two new *Marasmiellus* species (Omphalotaceae, Agaricales) from Thailand. MycoKeys 109: 31–48. https://doi.org/10.3897/mycokeys.109.129791

Malysheva E, Malysheva V (2024) *Volvariella lanata* (Pluteaceae, Agaricales), a new species from the Middle Volga Region, Russia. Phytotaxa 636(1): 74–84. https://doi.org/10.11646/phytotaxa.636.1.6

Malysheva E, Malysheva V, Alexandrova A, Morozova O (2019) Observations on Pluteaceae in Vietnam. 1. New species and new records of *Volvariella*. Phytotaxa 408(4): 233–254. https://doi.org/10.11646/phytotaxa.408.4.1

Manimohan P, Vrinda KB, Leelavathy KM (1988) Rare agarics from southern India. Kavaka 16(1–2): 50–56.

Manimohan P, Thomas KA, Nisha VS (2007) Agarics on elephant dung in Kerala State, India. Mycotaxon 99: 147–157. https://doi.org/10.5962/p.419187

Massee G (1899) Fungi Exotici II. Bulletin of miscellaneous information (Royal Botanic Gardens, Kew) 1899: 164–185. https://doi.org/10.2307/4111355

Massee G (1912) Fungi exotici XIV. Bulletin of Miscellaneous Information (Royal Botanic Gardens, Kew) 1912(6): 253–255. https://doi.org/10.2307/4104579

Matheny PB, Curtis JM, Hofstetter V, Aime MC, Moncalvo JM, Ge ZW, Yang ZL, Slot JC, Ammirati JF, Baroni TJ, Bougher NL, Hughes KW, Lodge DJ, Kerrigan RW, Seidl MT, Aanen DK, DeNitis M, Daniele GM, Desjardin DE, Kropp BR, Norvell LL, Parker A, Vellinga EC, Vilgalys R, Hibbett DS (2006) Major clades of Agaricales: A multilocus phylogenetic overview. Mycologia 98: 982–995. https://doi.org/10.1080/15572536.2006.11832627

Mehrotra RS, Aneja KR (1990) An introduction to mycology. New Age International, New Delhi, India.

Menolli Jr N, Capelari M (2008) Records and two new species of *Volvariella* (Pluteaceae, Agaricales) from Brazil. Mycotaxon 106: 385–398. https://doi.org/10.5962/p.414234

Miller MA, Pfeiffer W, Schwartz T (2012) The CIPRES Science Gateway: Enabling high-impact science for phylogenetics researchers with limited resources. In: Proceedings of the 1st Conference of the Extreme Science and Engineering Discovery Environment: Bridging from the extreme to the campus and beyond. Association for Computing Machinery, New York, 39: 1–8. https://doi.org/10.1145/2335755.2335836

Mohanan C (2011) Macrofungi of Kerala. KFRI Handbook No. 27. Kerala Forest Research Institute, Peechi, Kerala, India.

Montoya L, Bandala VM, Esqueda M (2021) *Volvopluteus canalipes* comb. nov. (Pluteaceae) from the Sonoran Desert of Mexico. Phytotaxa 505(3): 275–285. https://doi.org/10.11646/phytotaxa.505.3.3

Murrill WA (1911) The Agaricaceae of tropical North America. Mycologia 3: 271–282. https://doi.org/10.1080/00275514.1911.12017682

Niego AGT, Sysouphanthong P, Thongklang N, Hyde KD, Phonemany P, Phookamsak R, Raspé O (2021) A new species of *Volvariella* and the first record of *Volvariella pulla* (Agaricales: Incertae sedis) from Thailand. Phytotaxa 480(3): 237–250. https://doi.org/10.11646/phytotaxa.480.3.3

Niveiro N, Albertó E (2012) Checklist of the Argentine Agaricales I. Amanitaceae, Pluteaceae and Hygrophoraceae. Mycotaxon 121: 499–500.

Orton PD (1986) Agarics and boleti 4—Pluteaceae: *Pluteus* and *Volvariella*. British Fungus Flora. Royal Botanic Garden, Edinburgh, UK, 99 pp.

Pathak NC, Ghosh R, Singh MS (1978) The genus *Volvariella* Speg. in India. In: Atal CK, Bhat BK, Kaul TN (Eds) Indian mushroom science–1. Indo-American Literature House, New Delhi, India, 117–129.

Pradeep CK, Vrinda KB (2007) Some noteworthy agarics from the Western Ghats of Kerala. Journal of Mycopathological Research 45(1): 1–14.

Pradeep CK, Vrinda KB, Mathew S, Abraham TK (1998) The genus *Volvariella* in Kerala State, India. Mushroom Research 7(2): 53–62.

Rambaut A, Drummond AJ (2012) FigTree version 1.4.0. http://tree.bio.ed.ac.uk/software/figtree

Rath GC (1962) The genus *Volvariella* Speg. in Lucknow. Journal of the Indian Botanical Society 41: 524–530.

Rathnayaka AR, Tennakoon DS, Jones GEB, Wanasinghe DN, Bhat DJ, Priyashantha AH, Stephenson SL, Tibpromma S, Karunarathna SC (2024) Significance of precise documentation of hosts and geospatial data of fungal collections, with an emphasis on plant-associated fungi. New Zealand Journal of Botany 63(2–3): 462–489. https://doi.org/10.1080/0028825x.2024.2381734

Ronquist F, Teslenko M, van der Mark P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP (2012) MrBayes 3.2: Efficient Bayesian phylogenetic inference and model choice across a large model space. Systematic Biology 61: 539–542. https://doi.org/10.1093/sysbio/sys029

Roy Das A, Saha AK, Joshi SR, Das P (2017) Wild edible macrofungi consumed by ethnic tribes of Tripura in Northeast India with special reference to antibacterial activity of Pleurotus djamor. International Food Research Journal 24: 834–838.

Senthilarasu G, Sharma R, Singh S (2012) A new species of *Volvariella* from India. Mycotaxon 119: 467–476. https://doi.org/10.5248/119.467

Shaffer RL (1957) *Volvariella* in North America. Mycologia 49: 545–579. https://doi.org/10.1080/00275514.1957.12024669

Shaffer RL (1962) Synonyms, new combinations, and new species in *Volvariella* (Agaricales). Mycologia 54: 563–572. https://doi.org/10.1080/00275514.1962.12025036

Singer R (1986) The Agaricales in modern taxonomy. 4th edn. Koeltz Scientific Books, Koenigstein, Germany, 981 pp.

Singer R, Digilio APL (1951) Pródromo de la flora Agaricina Argentina. Lilloa 25: 6–461.

Spegazzini C (1898) Fungi Argentini novi vel critici. Anales del Museo Nacional de Historia Natural de Buenos Aires 6: 365 pp.

Stamatakis A (2014) RAxML version 8: A tool for phylogenetic analysis and post-analysis of large phylogenies. Bioinformatics (Oxford, England) 30: 1312–1313. https://doi.org/10.1093/bioinformatics/btu033

Swargiari BN, Buragohain R (2018) Wild edible mushroom trade in the local markets by tribal people of Kokrajhar, Assam. NeBio 9: 109–116.

Tarafder E, Dutta AK, Acharya K (2022) New species and new record in *Agaricus* subg. *Minores* from India. Turkish Journal of Botany 46(2): 183–195. https://doi.org/10.55730/1300-008X.2681

Tarafder E, Dutta AK, Karunarathna SC, He MQ, Tian F, Acharya K (2023) *Agaricus* sect. *Xanthodermatei* (Agaricales) of West Bengal, India. Phytotaxa 630(4): 245–265. https://doi.org/10.11646/phytotaxa.630.4.1

Varga T, Krizsán K, Földi C, Dima B, Sánchez-García M, Sánchez-Ramírez S, Szöllősi GJ, Szarkándi JG, Papp V, Albert L, Andreopoulos W, Angelini C, Antonín V, Barry KW, Bougher NL, Buchanan P, Buyck B, Bense V, Catcheside P, Chovatia M, Cooper J, Dämon W, Desjardin D, Finy P, Geml J, Haridas S, Hughes K, Justo A, Karasiński D, Kautmanova I, Kiss B, Kocsubé S, Kotiranta H, LaButti KM, Lechner BE, Liimatainen K, Lipzen A, Lukács Z, Mihaltcheva S, Morgado LN, Niskanen T, Noordeloos ME, Ohm RA, Ortiz-Santana B, Ovrebo C, Rácz N, Riley R, Savchenko A, Shiryaev A, Soop K, Spirin V, Szebenyi C, Tomšovský M, Tulloss RE, Uehling J, Grigoriev IV, Vágvölgyi C, Papp T, Martin FM, Miettinen O, Hibbett DS, Nagy LG (2019) Megaphylogeny resolves global patterns of mushroom evolution. Nature Ecology & Evolution 3: 668–678. https://doi.org/10.1038/s41559-019-0834-1

Vázquez LS, Guzmán-Dávalos L, Guzmán G (1989) Contribution to the knowledge of the species of the genus *Volvariella* in the state of Jalisco. Revista Mexicana de Micología 5: 169–179.

Vilgalys R, Hester M (1990) Rapid genetic identification and mapping of enzymatically amplified ribosomal DNA from several *Cryptococcus* species. Journal of Bacteriology 172: 4238–4246. https://doi.org/10.1128/jb.172.8.4238-4246.1990

Vizzini A, Contu M, Justo A (2011) Additional records of *Volvariella dunensis* (Basidiomycota, Agaricales): Morphological and molecular characterization. Mycotaxon 117: 37–43. https://doi.org/10.5248/117.37

Vizzini A, Alvarado P, Consiglio G, Marchetti M, Xu J (2024) Family matters inside the order Agaricales: Systematic reorganization and classification of incertae sedis clitocyboid, pleurotoid and tricholomatoid taxa based on an updated six-gene phylogeny. Studies in Mycology 107: 67–148. https://doi.org/10.3114/sim.2024.107.02

Vu D, Groenewald M, de Vries M, Gehrmann T, Stielow B, Eberhardt U, Al-Hatmi AMS, Groenewald JZ, Cardinali G, Houbraken J, Boekhout T (2019) Large-scale generation and analysis of filamentous fungal DNA barcodes boosts coverage for kingdom fungi and reveals thresholds for fungal species and higher taxon delimitation. Studies in Mycology 92: 135–154. https://doi.org/10.1016/j.simyco.2018.05.001

White TJ, Bruns T, Lee S, Taylor JW (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis MA, Gelfand DH, Sninsky JJ, White TJ (Eds) PCR Protocols: A guide to methods and applications. Academic Press, New York, 315–322. https://doi.org/10.1016/b978-0-12-372180-8.50042-1

Zheng DG, Lu WH, Han MY, Dai DQ, Zhang LJ, Elgorban AM, Kumla J, Suwannarach N, Tibpromma S, Chukeatirote E, Karunarathna SC (2025) *Volvopluteus yunnanensis* (Pluteaceae, Agaricales), a novel species from Yunnan Province, China. Phytotaxa 706(3): 269–280. https://doi.org/10.11646/phytotaxa.706.3.5

Zhu XT, Liu LJ, Wang XQ, Dang YX (2025) Two new species of *Volvopluteus* (Pluteaceae, Agaricales) from Northwest China. Phytotaxa 718(2): 133–143. https://doi.org/10.11646/phytotaxa.718.2.5